METHOD AND CONTROL DEVICE FOR TRIGGERING SOLENOID VALVES ASSIGNED TO GAS-EXCHANGE VALVES

The present invention relates to a method and a device for triggering solenoid valves assigned to gas-exchange valves.

In the case of internal combustion engines it is known to replace the conventional valve

5   mechanism having camshafts by an electrohydraulic valve actuation. In such an electrohydraulic valve actuation, the gas-exchange valves are assigned solenoid valves, which control the inflow and outflow of a pressurized fluid – an hydraulic oil – into the working chamber of an hydraulic working cylinder. The position of the corresponding gas-exchange valve is modified via the charge of the working chamber of the hydraulic working cylinder.

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The advantage of such an electrohydraulic valve timing is that the individual gas-exchange valves of the internal combustion engines may be actuated independently of each other. This provides great variability of the opening and closing instants of the gas-exchange valves. The variability is given both among the gas-exchange valves of different combustion chambers

15   and also among the gas-exchange valves of an individual combustion chamber. By appropriate coordination of the actuation of the solenoid valves, for instance, the valve actuation of two gas-exchange valves having the same function, i.e., two intake valves or two discharge valves, may be synchronized and any existing component tolerances or system-intrinsic deviations be compensated in synchronism.

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It is thus known from electrohydraulic valve actuations to ascertain a trigger signal for each individual solenoid valve in a control device, in time-synchronism with the crankshaft motion and possibly as a function of the driving state of the vehicle, the operating states of the internal combustion engine and also as a function of driver inputs. This signal is transmitted

25   to an output stage via an appropriate trigger line. In response to the actuation signal, the corresponding solenoid valve will then be triggered by means of the output stage.

This assumes that a separate control line between the control device and the output stage is provided for each solenoid valve, which causes high cabling expenditure and requires correspondingly higher computing power in the control device. Each actuating signal of the control device must be ascertained and generated in synchronism with the crankshaft.

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It is the objective of the present invention to reduce the wiring, computing and control outlay required for the activation of the solenoid valves while retaining an individual activation of the gas-exchange valve with respect to each other.

10   This objective is achieved by the method and the devices of the present invention.

The present invention relates to a method for triggering solenoid valves assigned to gas-exchange valves in an electrohydraulic valve actuation of an internal combustion engine having a plurality of combustion chambers. The solenoid valves assigned to the gas-exchange
15   valves may be activated independently of each other. To this end, crankshaft-synchronous trigger signals for solenoid valves of the internal combustion engine are ascertained in a control unit and transmitted to an output stage. The output stage controls the solenoid valves on the basis of the transmitted trigger signals. Each combustion chamber of the internal combustion engine has at least one intake valve and at least one discharge valve as gas-
20   exchange valve. According to the present invention, all solenoid valves of all gas-exchange valves of a combustion chamber form a solenoid valve set. In each case an activation profile is specified for all solenoid valves of a solenoid valve set. A crankshaft-synchronous activation signal is ascertained for each combustion chamber in the control unit and supplied to the output stage. The output stage controls the solenoid valves of the solenoid valve set
25   based on the activation signal of the cylinders in accordance with the activation profile stored for the individual solenoid valve.

This procedure is based on the fact that while considerable differences may exist between the solenoid valves of different gas-exchange valves of a combustion chamber, the activation of
30   all solenoid valves nevertheless follows a basic pattern, no great variance existing among equivalent solenoid valves of different combustion chambers. For that reason, an activation profile for each solenoid valve of a solenoid valve set is first generated in the control unit. This determination and the transmission of this information does have to be implemented rapidly, but not in synchronism with the crankshaft. The triggering of the individual solenoid

valves and their synchronization with respect to the crankshaft is implemented via the activation signal assigned to the corresponding combustion chamber. This ensures a combustion-chamber-individual synchronization, while the profile of the solenoid-valve activations of equivalent solenoid valves of the different combustion chambers corresponds to each other.

Due to the constant recalculation of the activation profiles for the solenoid valve set, the activation instants of the solenoids valves are able to be continuously adapted to the instantaneous driving state, and the driving wish of the driver may be implemented. In general, the variability and adaptability of the activation instants and activation durations of the gas-exchange valves of the internal combustion engine are maintained. Nevertheless, a synchronization of the recalculation with respect to the crankshaft is no longer required. The triggering may be implemented not only in synchronism with the crankshaft, but simultaneously in a time-synchronous manner as well.

According to an advantageous development of the present invention, it is provided that a specific activation profile be ascertained for each individual solenoid valve of the solenoid valve set. In this way, the activation of the solenoid valves is largely adapted to the driving state.

According to an advantageous development of the present invention, the activation signal for each individual cylinder is a binary signal, is ascertained in the control device and transmitted to the output stage. The binary signal is an easily generated signal whose information content is sufficiently high. Furthermore, it is advantageous if the activation signal for each individual cylinder is transmitted to the output stage on a cylinder-specific activation-signal line. In this way, a mutual decoupling of the activation signals of the various activation signals is achieved in a simple manner.

According to an advantageous development of the present invention, the output stage activates the solenoid valves of a cylinder on the basis of the value change of the activation signal of this cylinder in accordance with the corresponding activation profile. In particular in connection with a binary signal, a change from the first to the second value of the activation signal may have a different function than a change from the second to the first value of the activation signal. According to a preferred development, the activation of solenoid valves

assigned to the intake valves is carried out on the basis of a first value change between two values of the activation signal, and the activation of solenoid valves assigned to the discharge valves is carried out on the basis of a second value change between two values of the activation signal, the second value change differing from the first.

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According to a preferred development of the present invention, activation profiles are determined in the control device and transmitted via a data line to the output stage, where they are stored in a memory unit for use in the triggering of the solenoid valves. In the process, the activation profiles stored in the memory unit of the output stage are updated

10   during the operation of the output stage, to values preferably newly ascertained in the control device.

According to an advantageous development of the present invention, an activation profile is made up of a rectangular profile, which defines the onset and the duration of the activation of

15   the solenoid valve with respect to the instant established by the corresponding activation signal. According to a preferred development of the present invention, an activation profile is made up of the specification of four consecutively occurring time durations. The first time duration represents the length of a waiting time; the second time duration defines the duration of an application of a pull-up voltage at the solenoid valve; the third time duration determines

20   the length of a free-flight phase, and the fourth duration is the duration of an application of a holding voltage at a solenoid valve.

According to a preferred development of the present invention, an adaptation set is determined in the control device, the adaptation set including a solenoid-valve-specific

25   adaptation of the values of the activation profile for solenoid valves of a solenoid valve set. The values of the adaptation set are transmitted from the control device to the output stage, in particular by means of a second data line, which is separate from the first data line. For each solenoid valve set, one adaptation group of adaptation sets is preferably determined for all solenoid valves of the solenoid valve group. This measure allows an individual solenoid

30   valve activation of each solenoid valve. Different activation times with respect to the individual activation signal may also be achieved between equivalent solenoid valves of different solenoid valve sets. As a result, the individual solenoid valves remain independent of one another. This development of the present invention thus combines the advantage of reduced computing and control-line outlay and the advantages of an independent valve

actuation. This may be utilized in particular due to the fact that the temporal change in the characteristic of equivalent solenoid valves of different solenoid valve groups with respect to each other occurs relatively slowly, for instance as a result of deviating temperature developments among the solenoid coils of the solenoid valves, whereas the change in the

5   activation profiles of the solenoid valve sets occurs more often and more rapidly due to the driving condition.

The subject matter of the present invention is also a circuit arrangement for triggering solenoid valves assigned to gas-exchange valves. Trigger signals for the activation of the

10   solenoid valves are determined in a control unit. The control unit transmits signals to an output stage via corresponding lines. The output stage triggers the solenoid valves. According to the present invention, the lines between the control unit and the output stage are data lines for the transmission of activation profiles of solenoid valves and activation-signal lines for the crankshaft-synchronous activation of the actuation of the solenoid valves of cylinders in

15   response to activation signals.

According to the present invention, the required cabling between control unit and output stage is considerably reduced due to the provision of the activation-signal lines and the one data line. The number of lines is reduced because the output stage is able to trigger a

20   multitude of solenoid valves via the signal from an activation-signal line since the solenoid valves have been combined into solenoid valve groups.

According to an advantageous development, an activation-signal line between control unit and output stage is provided for each cylinder. According to an advantageous development of

25   a circuit arrangement according to the present invention, a second data line is provided to transmit the adaptation sets. Furthermore, it is also advantageous if the output stage includes a memory unit for storing at least the actuation profiles of the solenoid valve sets.

In addition, it corresponds to advantageous developments of the present invention if a

30   processing unit is provided in the output stage to ascertain the trigger signals from the activation profiles and the activation signals and possibly from the adaptation sets. ·

Furthermore, the present invention is also elucidated in greater detail in the exemplary embodiment shown in the drawing.

The figures show:

Figure 1   a schematic representation of a circuit configuration according to the present invention;

Figure 2   the flow chart of a method according to the present invention; and

Figure 3   the time characteristic of activation profile and trigger signal.

Figure 1 shows a circuit arrangement 10 according to the present invention in a schematic representation. The circuit arrangement has a control device 11 in which the activation profiles and the adaptation sets are ascertained. The control device is connected to output stage 18 via a plurality of lines 12, 13, 14. First data line 12 is used to transmit the activation profiles; second data line 13 transmits the adaptation sets. A memory 17 in which a first memory 15 is provided to store the activation profiles and a second memory 17 to store the adaptation sets, is available in output stage 18. In addition, activation-signal lines 12 are formed between control device 11 and output stage 18. One activation-signal line 12 is provided for each solenoid valve set MG1, MG2, MG3.

A processing unit 19 in output stage 18 ascertains the trigger signals from the activation profiles stored in memory 17 and the adaptation sets. The activation signals transmitted via activation-signal lines 12 energizes trigger lines 20, which in each case lead to a specific solenoid valve M1, ..., M5 of one of solenoid valve sets MG 1, ..., MG3. Same-numbered solenoid valves Mi of solenoid valve sets MG 1, ..., MG3 are solenoid valves that correspond to one another, which are triggerable by the same activation profile, possibly with the exception of an adaptation based on an adaptation set.

Solenoid valves M1, ... M5 in each case form a solenoid valve set MG1, ..., MG3. For the purpose of simplification, three solenoid valve sets having five solenoid valves Mi, i=1, ..., 5 in each case are shown in Figure 1. However, the number of solenoid valves Mi in a solenoid valve set is also adaptable according to the specific circumstances, as is the number of solenoid valve sets.

Figure 2 shows the flow diagram of a method according to the present invention in a schematic depiction. Steps 110, 111; 120, 121; 130, 131 are executed in the control unit and may by all means be carried out in parallel to one another. Steps 140 and 141 are executed in the output stage and are performed in parallel with the execution of the method steps

5   performed in the control unit.

According to step 110, activation profiles 24a, 24b (Figure 3) are ascertained and subsequently transmitted to output stage 18 via first data line 13 according to step 111. According to step 120, the adaptation sets are ascertained and transmitted to output stage 18

10   via second data line 14 according to step 121. According to step 130, activation signals 23 are determined in synchronism with the crankshaft rotation. According to step 131, they are then transmitted to output stage 18 via activation-signal lines 12.

According to step 140, the values required to trigger solenoid valve Mi are then determined in

15   output stage 18 on the basis of the available values of the adaptation sets and the activation profiles for a specific solenoid valve Mi (i=1, ... 5) of a solenoid valve set MGj (j=1, ..., 3). If an activation profile 24 for mutually corresponding solenoid valves Mi of solenoid valve sets MG1, ..., MG3 is specified by the four numerical values Ti1, Ti2, Ti3, Ti4 (cf. Figure 3), and an adaptation set for solenoid valve Mi of solenoid valve set MGj by the four values

20   Aij1, Aij2, Aij3, Aij4, a data set D(Mi, MGj) that characterizes the triggering according to the equation D(Mi,MGj)= (Ti1 *Aij1, Ti2*Aij2, Ti2*Aij2, Ti3*Aij3, Ti4*Aij4) will result for this solenoid valve. The values Aijn with n=1, ..., 4 of an adaptation set are thus scaling factors. According to step 141, solenoid valves Mi of solenoid valve groups MG1, ..., MG3 are activated according to the arrival of activation signals 23. As an alternative to scaling

25   using factors as it is shown here, the adaptation set may also include correction values directly, which are then linked to the solenoid valve set by addition.

Figure 3 shows the time characteristic of an activation signal 23 and, in parallel thereto, the characteristic of two activation profiles 24a, 24b. Activation profiles 24a, 24b are assigned to

30   one solenoid valve Mi in each case. Solenoid valve Mi having activation profile 24a is assigned to an intake valve of the internal combustion engine, while solenoid valve Mi having activation profile 24b is assigned to a discharge valve of the internal combustion engine, both solenoid valves being associated with a solenoid-valve set MGj. Activation signal 23 changes its value in a crankshaft-synchronous manner at the instant of ascending

edge slope 21, for instance from 0 to 1. Activation profiles 24a of solenoid valves Mi assigned to the intake valves are established according to this instant. The activation signal has a predefined duration and then changes its value again. This is represented by trailing edge 22. Activation profiles 24b of solenoid valves Mi assigned to the discharge valves are

5   calculated according to this instant.

Each activation profile of a solenoid valve Mi is made up of four consecutive time segments, Ti1, Ti2, Ti3, Ti4. Waiting time Ti1 indicates what time the activation of solenoid valve Mi begins after the particular edge. For the pull-up voltage duration Ti2, solenoid valve Mi has a

10   pull-up current applied. This is followed by a free-flight phase having duration Ti3 during which the solenoid valve is not energized. Next comes holding time Ti4 during which the solenoid valve is energized by a holding current.

Due to adaptation sets Aij, activation profiles 24a, 24b are able to be adapted to the individual

15   conditions of a solenoid valve Mi of solenoid-valve set MGj. Adaptation sets Aij of all solenoid valves Mi, i=1, ..., 5 of a solenoid-valve set form an adaptation group.